Dec. 26, 1961 R. J. OACE 3,014,263

MANUFACTURE OF NONWOVEN FABRICS

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FIG. 1

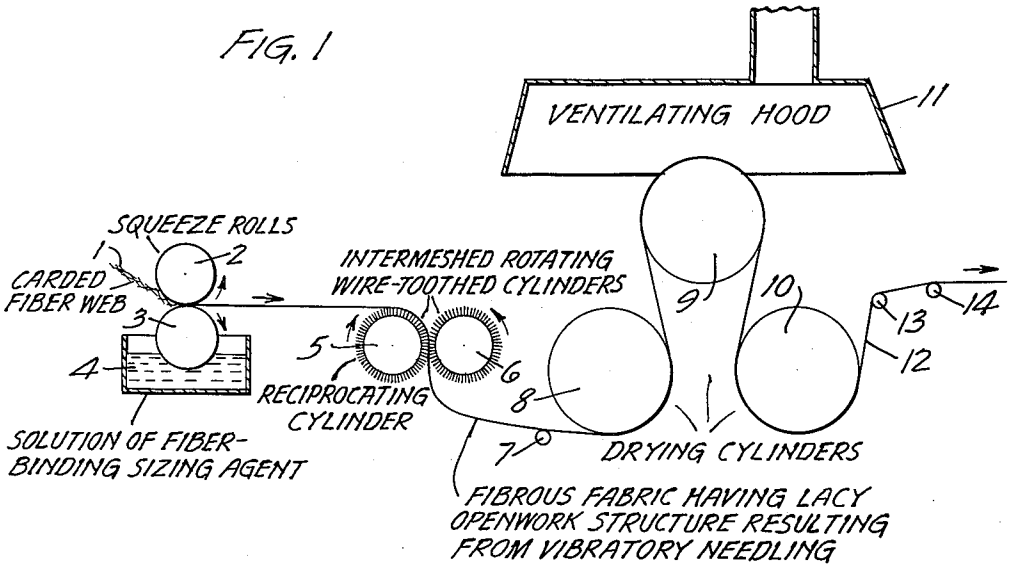


FIG. 2

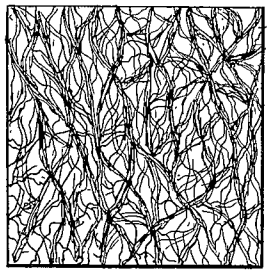
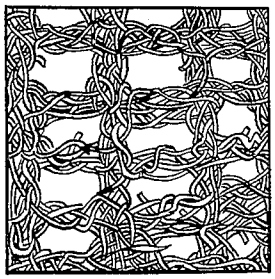


FIG. 3



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MANUFACTURE OF NONWOVEN FABRICS

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This invention relates to the manufacture of new and useful nonwoven fibrous fabrics having a lacy openwork structure; and to the novel procedures and equipment employed.

The invention provides unified lightweight fabrics which have a soft feel and hand, yet are strong and tough, resilient and conformable, and which are highly porous and absorbent even when wrapped or folded to form several layers. Such fabrics have utility, for instance, as dust cloths and polishing cloths, as cheese wraps in place of conventional woven cheesecloth wraps, as tobacco cloths, as bandage gauzes (including wraps for absorbent cotton), as cover wraps for absorbent sanitary napkins, and as lightweight disposable curtains.

This novel fabric is manufactured from a nonwoven tissue-like compacted web of staple fibers, such as is obtainable by use of a Garnett carding machine followed by soft-pressing of the carded web between rolls. The fibers are randomly positioned and pass over and under each other so as to be interlaced. Rayon staple fibers (preferably at least one inch in length), chopped from continuous viscose rayon filaments, are inexpensive and are well adapted for present usage in manufacturing fabrics having the above-mentioned fields of utility. Use of spun-dyed rayon fibers results in a colored fabric without need of a dyeing operation. However, other staple fibers, and mixtures of different fibers, can be employed in manufacturing fabrics having novel properties obtainable on account of the specific characteristics of the selected type of fiber—such as cellulose acetate fibers, nylon fibers, polyester fibers, hemp or rope fibers and even glass fibers. A further illustration of usage is in making fabrics to be coated with abrasive particles in the manufacture of flexible coated abrasive sheeting having a porous openwork structure.

The fibrous web is saturated with a solution of a fiber-binding sizing agent so that upon ultimate drying the fibers will be unified by adhesive bonding at their contact or crossing points; preferably without material effect on porosity and flexibility in making fabrics for the above-mentioned uses.

The production of unified tissue-like fibrous webs to provide nonwoven fabrics is already well-known.

The novelty in the present manufacturing procedure resides in continuously drawing the compacted tissue-like fibrous web, while still in a wetted condition and while under tension, between a pair of parallel intermeshed wire-toothed cylinders which oppositely rotate at the same peripheral speed and pierce and perforate the web from both sides. Each cylinder is provided with a large number per square inch of resilient needle-like wire teeth adapted to flex and move past intermeshed opposing teeth when they strike each other. One of the cylinders is rapidly oscillated along its axis to vibrate the resilient web-piercing teeth thereof transversely of the web and thereby enlarge the perforations by crowding, bundling and curving the affected fibers. This needling operation provides the wetted web with a large number of randomly irregular openings per square inch and a randomish openwork fabric structure, and the wet adhesion retains the fibers in their displaced positions pending drying and setting of the fibrous structure. The fabric is

then dried and may be cut into sheets, or slit and wound into rolls, of desired size; or it may be given a further processing (such as coating or impregnation) to convert it to a desired composite article for sale.

The needling operation permits of a lacy fabric product which is more porous and more absorbent of liquids, which has a softer feel and hand, and which is tougher and more conformable than is the product that would otherwise be obtained if this operation were omitted. The tensile strength is approximately the same but the "toughness" is greatly increased.

The "toughness" (as that term is here used) is proportional to the area under the stress-strain curve; as determined when a sample strip is subjected to gradual increase of tensile pull (stress) in a tensile-testing machine causing progressive elongation (strain) until rupture occurs. The stress-strain curve is a plot of proportional elongation values (vertical axis) against corresponding tensile values (horizontal axis), and machines are available which automatically plot the curve on a record paper as the test is made. When rupture (or incipient rupture) occurs, the elongation (strain) curve suddenly goes upward, and it is the area under the curve up to this point that is a measure of "toughness."

It is evident that even though two fabrics have approximately the same tensile strength, the stress-strain curves can be greatly different, indicative of a great difference in "toughness." The construction of the present fabric results in greater elongation or stretch as it is pulled, but it has approximately the same ultimate tensile strength; hence the area under the stress-strain curve is much greater than would be the case if the vibratory needling operation had been omitted.

This feature also makes it possible to produce a lighter fabric of adequate tensile strength that will be as tough as, or tougher than, a conventional type of heavier weight per unit area.

A preferred procedure for manufacturing the present fabrics will now be described in connection with the accompanying drawings, wherein:

FIG. 1 is a diagrammatic elevation view serving as a flow sheet and illustrating the apparatus employed in performing the novel process; and

FIGS. 2 and 3 are enlarged schematic views of illustrative products showing their fibrous, lacy, openwork structure. Such diagrams cannot effectively indicate the visual appearances of the fabrics due to the fineness and translucency of the actual fibers.

Staple textile fibers are formed into a continuous carded web by a Garnett machine or the like (not shown). An equivalent fibrous web may be made in other ways, as by use of a "Rando-Webber" machine (sold by Curlator Corp., Rochester, N.Y.). In any case the nonbundled staple fibers are randomly interlaced into a loose web forming a fluffy layer wherein the fibers cross over and under each other so as to be held together by mechanical and frictional forces. The resultant fibrous web may be identified as a "carded web" on the basis of characteristic fibrous structure even when not literally made by a carding procedure in the strict sense.

The dry carded fiber web **1** is fed through the nip of squeeze rolls **2** and **3**, the lower one of which dips into the bath **4** of fiber-binding sizing solution. This results in the fluffy web being compacted to a tissue-like condition and being wetted and impregnated without excess by the sizing solution.

The sized tissue, while still in a moist or damp state, is drawn horizontally to and down between a horizontal pair of driven, oppositely-rotating, wire-toothed cylinders **5** and **6**, which intermesh sufficiently to pierce the web from both sides, the axes of the cylinders being in the

same horizontal plane. Each cylinder is provided with a covering of card clothing which consists of a flexible foundation in which are set steel wire teeth so as to provide the cylinder with a large number of projecting needle-like teeth per square inch, the wires being surface ground so that the points define a cylinder concentric to the axis of rotation.

The first cylinder (5) rapidly oscillates along its axis, being driven by mechanism that both rotates and rapidly reciprocates the cylinder. The second cylinder (6) rotates only, and at the same peripheral rate, being restrained from substantial oscillation (which otherwise might result from vibratory pressures exerted by the intermeshing teeth of the oscillating cylinder).

The damp carded fibrous tissue is thereby gripped, pierced and ejected by the rotating wire-toothed cylinders, and is subjected to needling from both sides which results in a large number of holes per square inch. These holes are enlarged by the transverse vibratory action of the wire teeth of the reciprocating cylinder, which not only enlarges the holes formed by these teeth but also enlarges the holes formed by the teeth of the other cylinder. This enlargement of the holes results from a crowding, bundling and curving of the affected fibers of the tissue-like carded web. These fibers are able to move relative to each other and to be retained in their displaced state owing to the wet-adhesion, the fiber sizing not yet having dried so as to set the fibers.

Since the needles pull the fibrous web longitudinally while it is subjected to the transverse vibratory needle action, the holes are enlarged by the vibratory needling operation both in the longitudinal and transverse directions.

The resultant enlarged holes or openings have irregular shapes owing to the variability in the local fiber arrangement. The end result is a lacy openwork structure, having a large number of randomly irregular openings per square inch which are surrounded by a unified network of bundled and interlaced sized fibers which provide the body of the transformed web. As illustrated in FIGS. 2 and 3, a variety of structures can be obtained by variation of processing factors, such as type of fiber web, type and quantity of fiber-binding sizing solution retained in the damp web, type of wire-toothed cylinders and vibratory effect. In FIG. 3 the structure has a more pronounced bundling of fibers and a more cloth-like appearance than is true of the FIG. 2 structure; and is shown on a more highly enlarged scale.

The moving fabric web leaves the needling cylinders at a slower rate of travel than upon entering, due to the intervening transformation which causes a shortening of the web. The drape weight of the moving fabric makes it fall free of the cylinders in passing to and over the idler roll 7 which is located below and forwardly of the needling cylinders.

The moving web is then dried by engagement with a series of rotating heated drying cylinders, 8, 9, and 10, located below a forced-draft ventilating hood 11, thereby unifying the fabric by setting the fibers due to adhesive interbonding by means of the dried sizing agent. The sizing also serves to prevent fuzzing. The dried sizing on the fibers may be so thin and imperceptible that it does not appreciably affect the feel, hand, porosity or appearance of the product. Drying on cylinders prevents warping and distortion of the web and results in a smooth flat product.

The dried unified fabric product 12 passes over idler rolls 13 and 14 to a wind-up machine (not shown) where it is wound into large stock rolls.

Example

This example provides a description of details involved in a preferred process of manufacturing a novel fabric of this invention. A general description of the process, apparatus and product has already been provided.

The carded fiber web (1) that constitutes the starting material of the novel process is formed of staple viscose rayon fibers (medium or regular tenacity, 1½ denier, 1¼ inch length) and has a weight of about ½ ounce per square yard. The web is 40 inches wide.

The driven squeeze rolls (2 and 3) have a diameter of 6 inches and a length of 44 inches. The upper one is rubber-covered and rough-surfaced to provide a non-sticking resilient tractive surface, while the lower one (which dips into the sizing bath) has a knurled steel surface. The lineal rotation speed is adjusted to synchronize with that of the needling cylinders so as to minimize tension of the web. The roll pressure is adjusted so that excess sizing solution is squeezed out and the fluffy carded fiber web is compacted, resulting in a damp tissue-like fibrous web. This soft-pressing action is entirely different from the hard-pressing that occurs when a fabric is calendered between hard-surfaced calender rolls.

The sizing bath (4) is an aqueous dispersion of an acrylate polymer latex which serves as a water-insoluble fiber-binding sizing agent in the product. The following illustrative recipe is suitable; all parts being by weight:

	Parts
Aqueous dispersion of acrylate polymer binder (dry solids basis) (such as "Rhoplex B–15," sold by Rohm & Haas Co., which contains 46% acrylic polymer solids)	6.65
Wetting agent (such as "Triton GR–5," sold by Rohm & Haas Co.)	0.05
Direct cellulose dye (such as "Pontamine Scarlet B," sold by Du Pont)	0.01
Water added to make a total of 100 parts.	

The wetting agent and dye are optional. A colored fabric can be obtained without dyeing by utilizing spun-dyed rayon staple fibers.

This procedure provides an ultimate dry solids sizing weight of about 4 lbs. per thousand square yards of dry fabric product, and provides a tinted product such as is desirable for dust cloth usage. This sizing polymer is flexible and rubbery. Although it may have a slight tackiness if cast into a dried film, the actual dried fiber sizing is extremely thin and imparts no feeling of tackiness to the fabric product. (Sizings which do impart tackiness to the fabric may be used if desired.) Other fiber-binding sizing agents can be used as will be evident to those skilled in the art of textile fiber sizings.

The intermeshing wire-toothed needling cylinders 5 and 6 are steel cylinders of 6 inch diameter which are spirally wrapped with 2 inch width card clothing which has a resilient (rubber) foundation carrying 128 needle-like wire teeth per square inch, extending at right angles to the foundation, to provide a wire-toothed cylinder length of 44 inches. The teeth are resilient and can suitably be formed of No. 26 gauge steel wire. They have a free length of approximately ⅜ inch. The axial spacing of the cylinders is adjusted to provide an optimum degree of intermeshing of the wire teeth during rotation, a distance of about ⅛ inch being suitable with the present arrangement. The resiliency of the teeth permits teeth which strike each other to flex and move past without bending or breaking. The tips are ground so that the points define a cylinder concentric to the axis.

These cylinders are oppositely driven at the same peripheral wire-tip rotation speed of 34 feet per minute; the damp fibrous tissue from the squeeze rolls entering under tension at a rate of 34 feet per minute and leaving at substantially this same speed; so that the lineal speed of the web is maintained during its transformation. The axle of the first cylinder (5) is oscillated lengthwise by a crank mechanism to provide 500 oscillations per minute with a travel of about 5/32 to 7/32 inch. The result is that the fibrous fabric, pierced from both sides, is provided with a large number of enlarged openings per square inch, resulting in a lacy openwork structure.

The successive operations result in some decrease in the width of the fibrous web. The web has a width of 40 inches in going through the squeeze rolls, which is reduced at 39 inches as it enters the needling cylinders owing to tension on the non-unified damp fibrous tissue. There is no reduction in width during the needling operation. Tension during the subsequent travel of the web further reduces the width to 37½ inches by the time the fabric product is wound up.

A typical product of this specific procedure, after drying, has a tensile strength of about 3 lbs. per inch width and an average caliper thickness of about 5 mils; and it has a structure similar to that indicated in FIG. 2.

This product has been found to be very effective as a dust cloth, either dry or damp. A crumpled sheet has a resilient or springy feel. The sheet can be rinsed and dried for reuse several times owing to its water-resistant structure.

The present vibratory needling process is not limited to the manufacture of those particular types of fibrous sheet products previously described herein which are made from dry-formed carded webs. It has been found that desirable fabric products having a lacy openwork structure can also be made from water-laid tissue-like papers formed of staple paper-making fibers which are at least ¼ inch long and interlaced so as to be capable of displacement to provide the desired lacy openwork structure. A preferred example of such paper is a tissue made of rope fibers. This operation may be performed in conjunction with paper manufacturing by locating the wire-toothed cylinders so that the damp wet-pressed paper web, impregnated with a fiber-binding sizing agent, is led directly thereto for processing and is thereafter dried, with or without calendering. Or a dry unsized manufactured paper can be rewetted with an aqueous solution of the fiber-binding sizing agent and, while still damp, subjected to the present type of processing to obtain a porous openwork structure, followed by drying. Products somewhat resembling those made from carded webs can be manufactured from papers containing relatively long fibers, as in the case of hemp (rope) fiber tissues and tissue papers made from rayon, nylon or glass fibers, or mixtures of fibers.

I claim:

1. A process of making a unified, lightweight, porous, nonwoven, fibrous fabric of the character described; which comprises forming a nonwoven compacted tissue-like

wetted web of randomly interlaced staple fibers impregnated without excess by a solution of fiber-binding sizing agent which permits of motion and displacement of the web fibers relative to each other and retention in displaced positions; continuously drawing the wetted web under tension between a pair of parallel intermeshed wire-toothed cylinders which oppositely rotate at the same peripheral speed and pierce and perforate the web from both sides, each cylinder being provided with a large number per square inch of resilient needle-like wire teeth adapted to flex and move past intermeshed opposing teeth when they strike each other, one of the cylinders being rapidly oscillated along its axis to vibrate the resilient web-piercing teeth thereof transversely of the web and thereby enlarge the perforations by crowding, bundling and curving the affected fibers, such as to provide the wetted web with a large number of randomly irregular openings per square inch and a randomish lacy openwork fabric structure; and thereafter drying the web to obtain a unified fabric.

2. A process according to claim 1 wherein the web is a carded web of viscose rayon staple fibers having a length of at least one inch and weighing about one-half ounce per square yard, and the fiber-binding sizing agent is a water-insoluble rubbery acrylate polymer employed in such small proportion that it does not appreciably affect the porosity of the product; the fabric product having a "toughness" as (herein defined) which is substantially greater than it would have if it had not been acted upon by the wire-toothed cylinders.

3. A nonwoven lacy fibrous fabric made by the process of claim 1.

4. A nonwoven lacy fibrous fabric made by the process of claim 2.

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